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Structural Characterization of High Explosives from Micrographs

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We perform image analysis of micrographs of high explosives such as PBX 9501 (95% high-melting explosives [HMX] and 5% polymeric binder) or X-0242 (92% HMX and 8% polymeric binder). The microstructural features of these materials are of great importance to the weapon-materials' community.

In order to extract features from micrographs, we employ several image segmentation techniques for the grey-level images. We either work on the original images or their Pulse-Coupled Neural Network (PCNN) smoothed [1] versions. Image segmentation is then performed while using either a simple spectral segmentation or a PCNN segmentation on the original or smoothed images [2], respectively.

The image processing steps are explained in detail in [2, 3]. First the blobs of the grains are enclosed with dilated contours [3]. Then the contour point set and the generated contour edges form the input to a constrained Delaunay tessellation. The subsequently applied Chordal Axis Transform (CAT) [5, 6, 7] provides a morphological decomposition of the grains into simplicial chain complexes of shape features (limbs and torsos). Using the average grey-levels in each triangle for torsos, we are able to separate individual grains from each other [2, 3]. The individual grains' area can be calculated while adding up the triangle areas for each grain. The grains aspect ratios are evaluated after the computation of minimum enclosing rectangles for each grain. Before we

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compute the CAT for the binder material, we remove potential holes in each grain. The lengths and widths of the binder segments can be read off directly from the lengths and widths of the binders limbs and torsos.

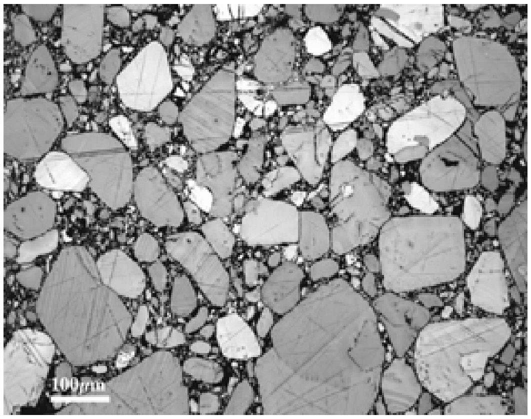

Figure 1.

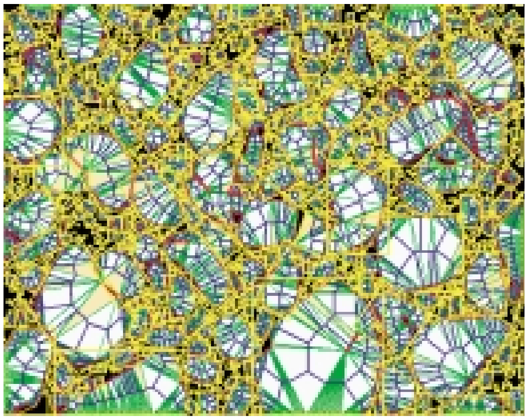

Figure 2.

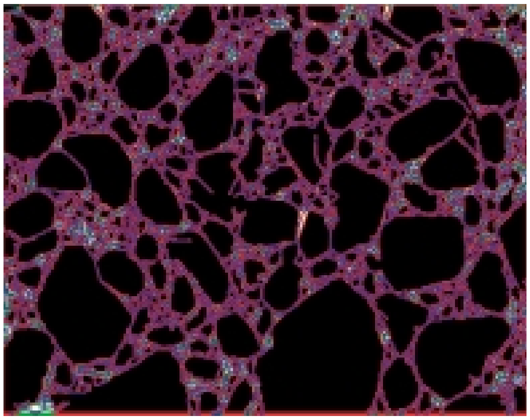

Figure 3.

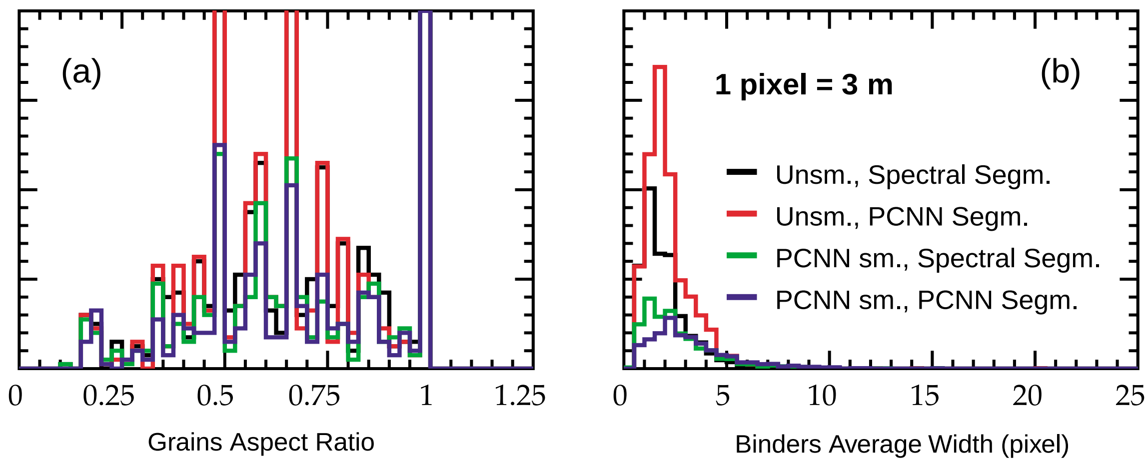

Figure 4.

Figures 1, 2, and 3 (top to bottom) show the original image of a X-0242 sample, geometrically processed HMX grains, and geometrically processed polymeric binder, respectively.

Figure 4 shows statistical distributions of (a) the grains aspect ratios, and (b) the binders average widths. We have plotted four curves in each plot referring to the four different cases of image segmentation, which we have used here. Although several features are different from scenario to scenario [2] (e.g., the total number of grains present in an image), we observe the following quantities, which are mostly invariant to the image segmentation procedure: the distribution of grain aspect ratios peaks around a value of 0.65, and the average grain separation is of the order of 6 μm for the given image resolution of 1 pixel = 3 μm.

Finally, we would like to mention that our approach assumes that the grain density in two dimensions as read off from the micrograph is equal to the true 3-dimensional grain density for the explosive materials. Whether we can justify this assumption of isotropy and homogeneity is yet to be resolved.

[1] A. N. Skourikhine, L. Prasad, B. R. Schlei, "Neural Network for Image Segmentation," Proceedings of SPIE's 45th Annual Meeting, San Diego, CA, Vol. 4120 (2000) 28.

[2] B. R. Schlei, L. Prasad, A. N. Skourikhine,"Geometric Morphology of Granular Materials,'' Proceedings of SPIE's 45th Annual Meeting, San Diego, CA, Vol. 4117 (2000) 196.

[3] B. R. Schlei, L. Prasad, "Granular Materials ImageAnalysis", *Special Feature.2000, Supplement to the T-Division Self-Assessment for 1999/2000*, Los Alamos, April 2000, LA-UR-00-1, p. 15.

[4] B. R. Schlei, L. Prasad, "A Parallel Algorithm for Dilated Contour Extraction from Bilevel Images," Los Alamos Preprint LA-UR-00-309, cs.CV/0001024.

[5] L. Prasad, "Morphological Analysis of Shapes," CNLS Newsletter, No. 139, July '97, LALP-97-010-139, Center for Nonlinear Studies, Los Alamos National Laboratory.

[6] L. Prasad, R. Rao, "Morphological Analysis of Shapes", in *Special Feature, Supplement to the T-Division Self-Assessment for 1997/1998*, Los Alamos, May 1998, LA-UR-98-1150, p. 107.

[7] L. Prasad, R. L. Rao, "A geometric transform for shape feature extraction", Proceedings of SPIE's 45th Annual Meeting, San Diego, CA, Vol. 4117 (2000) 222.

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